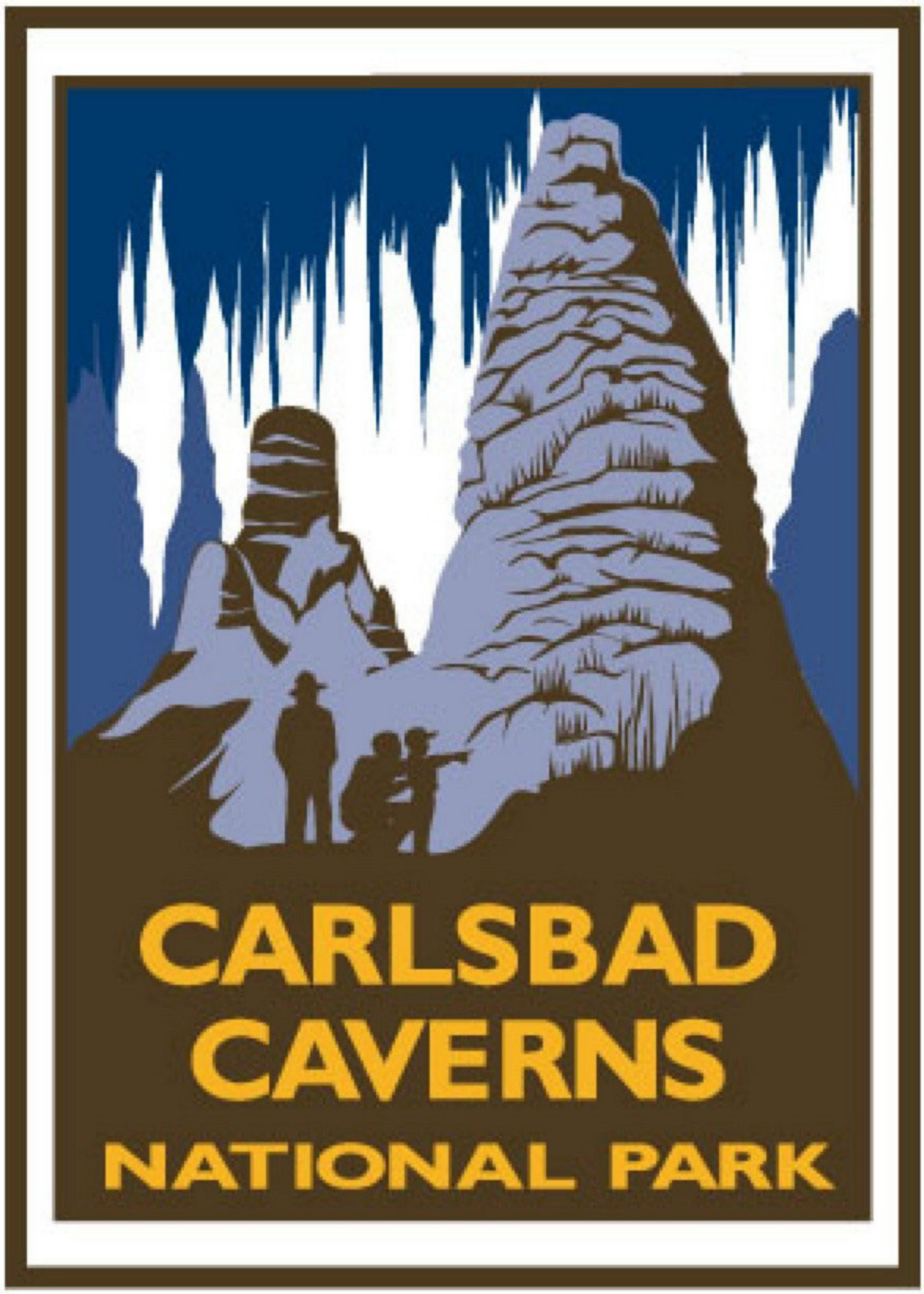
Caves, Canyons, Cactus & Critters

A curriculum and activity guide for Carlsbad Caverns National Park

Middle School Geology



Caves, Canyons, Cactus & Critters
Geology Curriculum

Mother Nature’s Gravel Company

Anyone hiking the backcountry of Carlsbad Caverns National Park will immediately notice that it’s very rocky. Big angular rocks breaking off cliffs on the hillsides, round, bowling ball size rocks, and sand and gravel bars in the canyon bottoms all make up a major part of the landscape. The processes that take the limestone, sandstone, and shale bedrock of the Guadalupe Mountains and turn them into smaller sediments are called weathering and erosion.

The processes that break rocks into smaller pieces are referred to as weathering. Mechanical weathering breaks the rocks into smaller pieces without changing their chemical composition. Examples of mechanical weathering are root pry, ice wedging, abrasion, and differential heating. With chemical weathering, the chemical composition of the rock is changed. Examples are reactions with water, acids, and oxygen. The smaller pieces of rock that result from weathering are called sediment. In Carlsbad Caverns National Park, all of these processes are active.

The processes that move sediments are referred to as erosion. The primary agents of erosion are wind, water, gravity and ice (glaciation). In Carlsbad Caverns National Park, all of these, except ice, are active processes.

In this unit, activities will explore weathering by ice wedging and by acids, two of the most active processes in the park. Erosion by wind and water will be the subjects of activities as well.

Ice Wedgies!

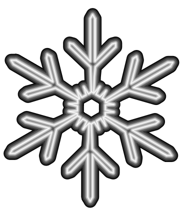
What breaks rocks apart in the mountains?

Summary: Students will model the effect of freeze/thaw cycles on the weathering of rocks.
Duration: Part of two 50-minute class periods with overnight activity.
Setting: Classroom
Vocabulary: abrasion, differential heating, ice wedging, mechanical weathering, root pry
Standards/Benchmarks Addressed: SC2-E3, SC5-E2, SC6-E1, SC12-E1, SC12-E3

Objectives
Students will:

- describe the four major types of mechanical weathering.
- model ice wedging.

Background



The processes by which a rock is broken into smaller pieces without being changed chemically are called *mechanical weathering.* The most common of these processes are *root pry*, abrasion, differential heating, and ice wedging. When a plant's root grows through a crack in a rock, it begins to exert a gradual pressure on the sides of that crack. Slowly, over time, the pressure increases and the crack widens until, eventually, the rock is broken.

Abrasion is the wearing away of rocks by solid particles carried by wind, water, or other forces. Classic examples of weathering can be found at Arches National Park, Zion National Park, and Bryce Canyon National Park. In all of these Utah parks, sand carried on the wind has carved unusual shapes and spectacular windows. Along the bottoms of the canyons in the Guadalupe Mountains in Texas and New Mexico are places where the bedrock has been scoured smooth by abrasives carried in floodwater.

Differential heating is the stress created within a rock when the outer part of the rock expands and contracts with daily heating while the interior of the rock remains stable. The stresses generated by this flexing eventually cause layers or sheets to break loose and peel away from the surface of the rock. Another form of differential heating called intergranular disintegration occurs in rocks composed of a mix of light and dark colored minerals. When exposed to sunlight, dark colored minerals absorb more of the energy than the light minerals and heat at a different rate. This difference in heating rates, combined with differences in thermal expansion rates, causes stress between the mineral crystals. With the cycle repeated daily over several years, the crystals eventually break apart from one another. Running your hand across granite or diorite weathered this way will yield a handful of crystals resembling salt and pepper.

Ice wedging begins when water seeps into cracks in a rock. It is dependent on cycles of nightly freezing and daily thawing of that water. As the water freezes at night and changes state from a liquid to a solid, the molecules of H_2O align into a repeating pattern known as an ice crystal. This orderly arrangement of molecules takes up more space than the same molecules in a liquid state. Due to this, the ice expands approximately 9% and exerts great pressure on the sides of the crack. During the day, the water melts, possibly more water seeps into the crack, and the cycle begins again. As these freeze/thaw cycles continue over a span of years, the crack continues to widen until the rock is broken. This method is most effective in regions that have a maximum number of freeze/thaw cycles throughout the course of a year. During the late fall to early spring months, this would be an active process in the high Guadalupe Mountains.

Materials

- plastic one-liter soda bottles (one per three or four person group)
- marker that will mark on plastic bottle

Procedure

Warm up: Ask students to describe any processes they can think of that would turn big rocks into small rocks in nature. List and discuss these ideas.

Describe and discuss root pry, abrasion, and differential heating.

Discuss the concept of ice wedging.

Activity: This activity will involve leaving items in a freezer overnight.

1. Pour about 800 ml water in one-liter soda bottles and put cap on.
2. Mark the water level on the side of the bottle.
3. Place all bottles in a freezer overnight. Set them in a pan or container that can hold the volume of water used, just in case.
4. Remove bottles from freezer immediately prior to use in class.
5. Have students mark level of ice in the bottle and make note of any deformations they see on the bottle.

Wrap Up: Discuss what was observed. Have the students hypothesize why the volume of water increases when it becomes ice.

Ask if any student has ever had pipes freeze and burst during winter. Discuss the effect that freezing would have on anything containing water.

Review ice wedging and incorporate observations from the lab into the discussion.

Assessment

Have students:

- list the forms of mechanical weathering.
- describe the processes by which the forms of mechanical weathering work.

Extensions

Have students design and perform experiments or demonstrations modeling one of the three other forms of mechanical weathering mentioned in the background material.

Have students make a list of any examples of mechanical weathering they observe over the course of one week.

Resources

Coble, Charles, et al. 1993. *Prentice Hall Earth Science.* Englewood Cliffs, NJ. Prentice Hall.

Feather, Ralph, et al. 1999. *Glencoe Earth Science.* Westerville, OH: Glencoe/McGraw-Hill.

Huff 'n' Puff

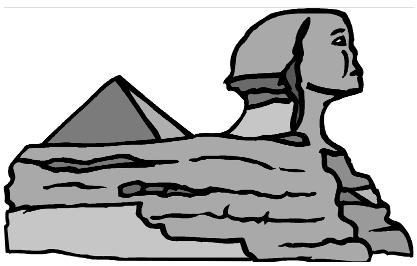
Why and how do sand dunes form?

Summary: Students will use information learned in class discussion to model sand dune migration.
Duration: One 50-minute class period
Setting: Classroom
Vocabulary: abrasion, deflation, deposition, desert pavement, slip face
Standards/Benchmarks Addressed: SC2-E3, SC5-E2, SC6-E1, SC12-E3

Objectives
Students will:

- describe how sand dunes form.
- describe the effect of obstacles on sand dune migration.

Background



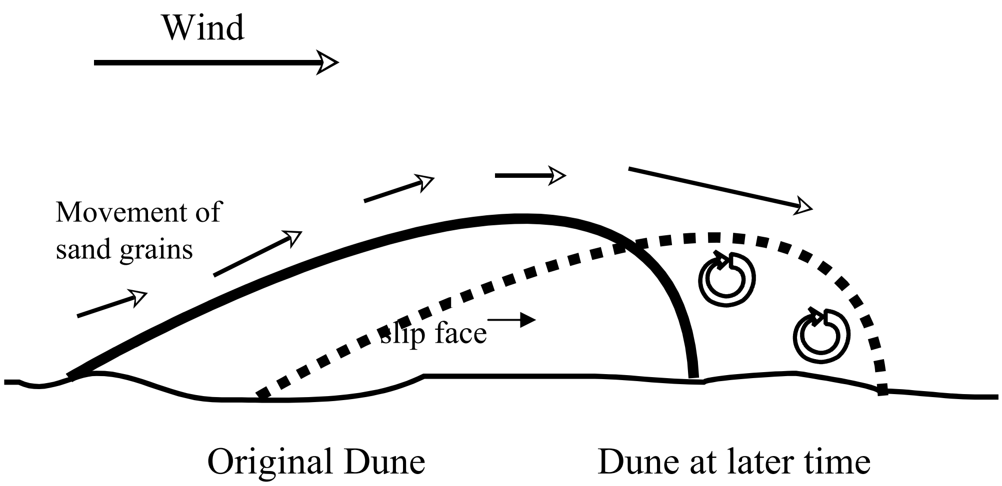
Energy is defined as the ability to do work or to move a mass a distance. Anyone who has been around the Carlsbad area during spring knows that, by this definition, wind has energy. Wind regularly fills the air with dirt and debris it has picked up and moves the debris to new locations.

Two words used to describe erosion by wind are deflation and abrasion. When the wind blows across loose particles and picks up or moves the smaller ones, it is referred to as *deflation.* When wind-borne objects strike stationary objects or sediment and loosen them so that they too are eroded, it is referred to as *abrasion*. *Deposition* occurs when the wind slows and loses energy. Without the energy it once had, the wind can no longer carry the sediments it once did and they begin to settle to the ground.

Several factors can make it difficult for wind to pick up sediments. Sediment size is one such factor. As the wind blows across an area containing several sizes of loose sediment, it begins to carry away the smaller particles, leaving the larger ones behind. Over time, these larger sediments will form a protective coating on the ground, preventing the wind from further deflating the smaller sediments. This protective layer is called *desert pavement* and is seen in the Carlsbad Caverns National Park area.

Two other factors affecting the ability of wind to deflate sediments are vegetative cover and moisture. Vegetative cover protects the soil under it from wind and helps to keep the soil moist. When sediments are moist, they will remain packed and resistant to deflation. When vegetation is removed, the soil is exposed to the sun. As the soil begins to dry, it can be deflated easier by the wind. In a time of drought, this is a natural process. A lack of rainfall will cause vegetation to die. As it dies, the soil underneath will be exposed to the wind and eroded. Any human activity that disrupts vegetative cover can also accelerate wind erosion. Such activities are surface mining, farming, and construction. During the 1930s, in the central part of the United States, farmland was left in an unvegetated state due to drought. Wind moving across these fields deflated great quantities of topsoil and carried it as far as New England and the North Atlantic Ocean. Today, in an effort to prevent or slow these “dust bowl” type storms, windbreaks are often planted along fields. Windbreaks are typically rows of trees planted between fields. These rows of trees disrupt and slow the flow of air at ground level and inhibit its ability to deflate soil in fields.

The wind deposit with which most people are familiar is sand dunes. Sand dunes are mounds of sand that migrate in directions dictated by the prevailing winds in an area. As the wind moves across the windward side of the dune, the side with the more gradual slope, it deflates, the sediments on that side of the dune and carries or bounces them up the dune to the top. As the wind moves across to the back, or leeward, side of the dune, its speed slows and it looses energy. This steeper side where sediments are deposited is referred to as the *slip face.* Near the dune, the wind will form eddies, or backward rotating areas. In these lower energy areas, sand carried from the front of the dune will be deposited. In this way, the dune migrates in the direction the wind is blowing.



Materials

- sand
- flour
- gravel
- rocks 1" - 2" diameter
- 9" x 13" baking pans or similar size tubs
- soda straws
- cardboard sheets
- tape
- paper for sketching

Procedure
Warm up: Define energy for the class. Ask for examples of things in nature that have energy. For each example, ask for proof.

If students do not suggest it, ask, "Does wind have energy?" Answers may vary. If some students say no, you may want to ask about such things as sailboats, tornadoes, and springtime in the southwest.

Once it has been established that wind does have energy, discuss deflation, abrasion and deposition. Ask students for examples of ways to keep the wind from eroding soils. Discuss the dust bowl conditions of the 1930s. Describe desert pavement and ask where students think it might be found.

Ask students if anyone has ever visited sand dunes anywhere, including White Sands National Monument, Great Sand Dunes National Monument, or the sand dunes east of Carlsbad, New Mexico. Ask about the shape of the dunes. Describe and discuss sand dune movement.

Activity

1. Mix the sand, gravel, and flour thoroughly.
2. Cover the bottom of a pan or washbasin with 1/2 inch of the mixture. Put one or two of the rocks in the pan near the middle. Use one setup per group of two to four students. Allow the students to "sculpt" the landscape in any form they choose but establish the guideline that once the wind starts blowing, they cannot touch the sediments in the pan again.
3. Have students use three or four pieces of cardboard and tape to construct a barrier around their "dune field."
4. Using the straw, students will ***GENTLY*** blow the sand from one side of the pan. *The wind must always come from the same side throughout the activity*. Tell students that if the sediments are not moving, they need to make more wind. If their table looks like a field during the dust bowl days, they do not need as much wind.
5. Have students sketch their dune field four or five times during the activity at an interval of about three or four minutes between sketches. The first sketch should be drawn before beginning. In particular, have them sketch dunes and how they change, areas of deflation and deposition, what happens to sediments around the larger rocks, formation of desert pavement, and any place they see the sediments being sorted by size.

Wrap Up: After cleaning sand and flour off of tables or desks, ask students who have been to sand dunes if the features they saw in their pan looked familiar to what they have seen at areas with sand dunes. Ask students for examples of other areas where they've seen sediments pile up along the side of an object like the rock in their pan. Some examples might be along a street curb during a dust storm, and around the side of a house or fence during a sand storm or during a snowstorm.

Ask the students what can be done to prevent wind erosion. Suggestions should include planting vegetation and windbreaks.

Assessment
Collect sketches. Have students:

- define and explain *deflation, abrasion* and *deposition.*
- list three factors affecting wind erosion.
- describe two ways to prevent or slow wind erosion.
- describe how a sand dune moves.

Extensions
Have students:

- do internet or library research and gather photos of sand dunes from around the world.
- study the photos and attempt to determine the prevailing wind direction.
- identify any features in the photo designed to stop or slow wind erosion.
- compare and contrast the dunes to determine if dunes can have several different basic shapes. Have them research the various dune shapes (barchan dunes, transverse dunes, parabolic dunes, seif dunes, star dunes, dome-shaped dunes, and reversing dunes) and attempt to determine what types are found in each of the photos. (Barchan and seif are the most common)

Resources
Feather, Ralph, et al. 1999. *Glencoe Earth Science.* Westerville, OH: Glencoe/McGraw-Hill.

VanCleave, Janice. 1991. *Janice VanCleave's Earth Science For Every Kid.* New York, NY, John Wiley & Sons, Inc.

Flash Flood Fantasy

Why is water the primary agent of erosion in the arid southwest?

Summary: Students will observe and describe gully and canyon erosion in the desert southwest using stream trays they have made.
Duration: Two 50-minute class periods
Setting: Classroom and outside
Vocabulary: alluvial fan, arroyo, bar, canyon, meander, undercut bank, waterfall
Standards/Benchmarks Addressed: SC2-E3, SC5-E2, SC6-E1, SC12-E3

Objectives
Students will:

- name features formed by moving surface water.
- describe erosion features formed in stream trays or canyon models.

Background

The four primary agents of erosion are wind, water, gravity, and ice. Of these, the most active on the earth's surface is water. Even in the semi-arid southwestern United States, water does more to sculpt the land than wind, ice, or gravity. Most of the precipitation in the area around Carlsbad Caverns National Park comes in the form of brief, heavy rainfall associated with thunderstorms. From a small, obscure mudflow along the flanks of North Slaughter Canyon to a road-blocking flash flood in Walnut Canyon, the effects of these periodic, intense rains can be seen throughout the park.

Most of the deposits and landforms seen along valleys where rivers flow year-round are similar to or identical to those formed by periodic flooding in the desert southwest. Among these are *canyons, arroyos*, *waterfalls*, meanders, bar deposits, undercut banks, and, at the mouths of canyons, alluvial fans. Canyons, arroyos, and falls are features familiar to anyone who has spent time in the mountains near a river that meanders its way past, flowing downhill. In fact, a bend in a river is called a *meander.* The deposits of rocks, gravel, and sand, rounded by the abrasive action of fast moving floodwater, are called *bars*. A close examination of bar deposits will reveal that the sediments in a bar deposit are sorted by size. As the water in a river or a flooding canyon flows around, over, and through obstacles, its velocity changes. These changes in velocity and energy result in sediments being sorted, or deposited in different places along a stream or canyon bottom. Often, the fast moving water along the outer edge of a meander will cut into the bank, leaving soil and plants or trees above. When this happens, it is referred to as an *undercut bank*.

As a flash flood roars down a canyon in the Guadalupe Mountains, or in similar fault-block mountains, it has a great deal of energy and moves sediment that is large in volume and large in size. Mountains like the Guadalupes are typified by deep canyons that cut suddenly through the face of an escarpment and open abruptly into flat plains or a flat valley floor paralleling the escarpment. As the highly energetic flood waters rush from the confines of the canyon and spread onto the flats beyond the canyon mouth, they slow and suddenly lose energy. As a result of this lost energy, the sediments carried by the flood begin to be deposited rapidly. A large, cone-shaped pile of flood debris and sediment called an *alluvial fan* is found at the mouth of canyons like those seen in the Guadalupe Mountains. Often, inactive areas of the fan will be overgrown with vegetation typical of the desert and canyon bottoms. However, arroyos leading from the canyon mouth will cut through these areas leading floodwaters and sediments to the areas of the fan where active deposition occurs.

Materials

- vinyl rain gutter cut in 2-foot sections
- endcaps for rain gutter – one per rain gutter section
- sand or dirt
- rocks – 1 or 2 inch diameter
- water source – 1-liter bottles with sport top and a refill source works great!

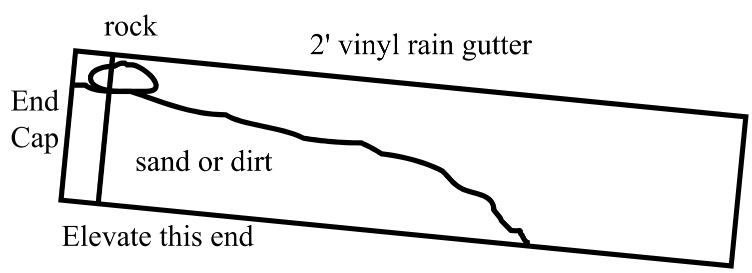
Procedure

Warm up: Ask students if any have ever seen a flash flood. Have students describe the effects of the flood that they observed during and after. Have them describe changes made in the landscape and on roadways and any sediment deposits they noticed.

Discuss the role that periodic flash flooding plays in shaping the landscape in and near Carlsbad Caverns National Park. Describe the various features associated with moving water.

Activity

1. Using 2-foot sections of vinyl rain gutter, prepare stream/canyon models as shown.



2. Fill each gutter with dirt approximately 2/3 full at the gutter end and slope to where dirt ends about 2/3 of the distance to the end (see drawing). The dirt can be packed some and sculpted so that the middle section is slightly lower than the edges. Place a rock on the dirt at the upper end. Water will be poured on this rock. If they wish, allow students to build small villages with “Monopoly” houses.
3. Be sure to do this part of the activity in an outside location where water and mud will not create a problem for others. Set the canyon model at a slope with the capped end three to four inches higher than the lower end. After this point, students should be instructed that they are ***not*** to touch or manipulate the dirt any further. From this point on, only the water will be allowed to do that work.
4. Instruct (and model) students to gently pour water on the rock and let it flow out the mouth of the canyon. This may take a few minutes since the dirt will absorb much of the water initially.

5. Once a stream begins to flow the length of the canyon, students are to stop and sketch the canyon, being sure to show where various features such as arroyos, falls, and bar deposits are forming.
6. Instruct students to continue gently pouring water to simulate periodic flash floods and stopping every three or four minutes to draw a new sketch, paying close attention to changes along the canyon.
7. Tell students to pay particular attention to deposits in, or near, the canyon mouth. Point out the alluvial fans that begin to develop just outside the canyon mouth. Instruct students to include these in their sketches.
8. Clean up the mess.

Wrap Up: Discuss the features students saw develop in their canyons. Ask if any have seen similar features in real life.

Assessment
Collect sketches. Have students:

- describe the various landforms and deposits associated with moving water.

Extensions
Have students:

- study the effect of slope on runoff and erosion by tilting the canyon models at several different heights.
- study the effect of vegetation on erosion by mixing grass in with the dirt.
- vary the intensity of water flow as a study on the effect of water speed on erosion.

Resources
Feather, Ralph, et al. 1999. *Glencoe Earth Science.* Westerville, OH: Glencoe/McGraw-Hill.

VanCleave, Janice. 1991. *Janice VanCleave's Earth Science For Every Kid.* New York, NY, John Wiley & Sons, Inc.

Natural Acids

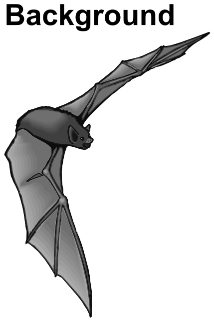
What makes those big holes in the ground?

Summary: Students will describe the source of various acids that form caves and will model the effect of acids on carbonate rocks.
Duration: One 50-minute class period
Setting: Classroom or lab
Vocabulary: acid, infiltration, karst, resurging streams, sinkholes, sinking streams
Standards/Benchmarks Addressed: SC2-E3, SC5-E2, SC6-E1, SC12-E3

Objectives
Students will:

- describe the sources of two cave forming acids.
- model the effect of acids on carbonate rocks.

Background



Natural formed acids weather rocks. The lesson *Stinky Gas and Alabaster* described the processes by which sulfuric acid from below can form caves like those in Carlsbad Caverns National Park. However, a different process forms most caves in carbonate rocks. Groundwater contains carbonic acid, the same weak *acid* that gives sodas their fizz, and can dissolve carbonate rocks like limestone. In arid regions, such as those in the desert southwest, insufficient rainfall prevents this from becoming a dominant cave forming process. However, in the eastern United States this process forms most caves. The longest cave system in the world, the Mammoth Cave – Flint Ridge system, was formed as mildly acidic groundwater dissolved a series of large, underground river passages beneath the sinkhole plain of southwestern Kentucky.

As rainwater falls, it absorbs some carbon dioxide from the surrounding air. However, most of the carbon dioxide in the groundwater comes from the soil the water passes through as it *infiltrates*, or sinks into the ground. As the groundwater moves through cracks, or joints, in the limestone bedrock it begins to slowly dissolve the rock. The chemical reactions involved in this process are shown below.

carbon dioxide + water

$CO_2 + H_2O$

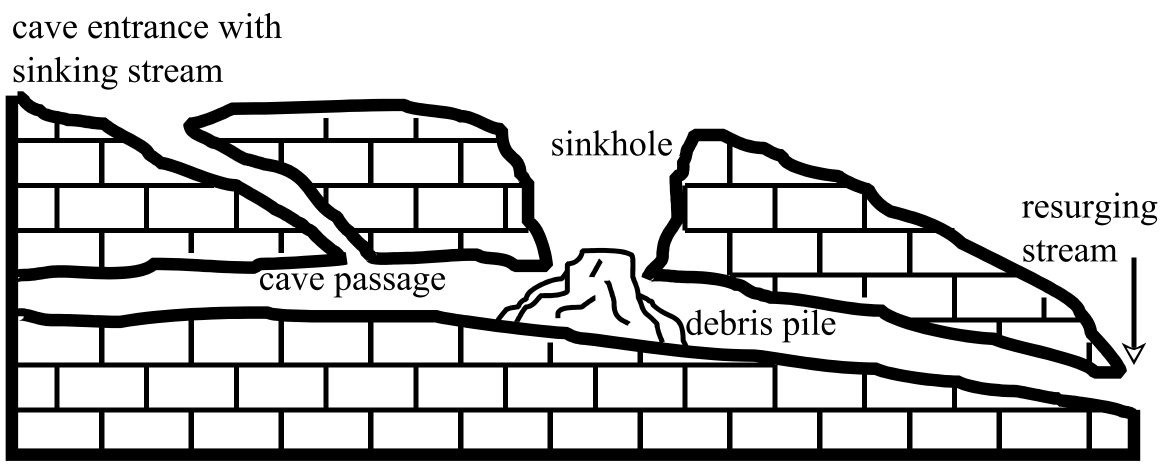
carbonic acid solution + calcium bicarbonate calcite

$H_2CO_3 + CaCO_3 \rightarrow Ca^{2+} + 2HCO_3^{1-}$

The rivers formed by this mildly acidic groundwater will flow gradually downhill until reaching a base water table or reemerging onto the surface as a spring. In Mammoth Cave National Park, the underground river eventually flows into the Green River, the base level river for the area. Cave passages in Mammoth Cave National Park have been formed on several levels. Older cave passages are located higher, corresponding to a time when they emerged into a shallower Green River Valley. As the Green River cut deeper into the valley floor, the underground rivers feeding into it cut deeper into the beds of limestone, creating newer, lower passages.

The dissolution of soluble rocks results in a number of surface features collectively classified as *karst*. Among these landforms are *sinking streams, resurging streams, sinkholes,* and cave entrances. Karst terrains cover about 12% of the earth's dry, ice-free surfaces. It is estimated that 25% of the world's population relies on karst aquifers to supply their water needs. As the joints in the limestone bedrock are enlarged, the rate of infiltration from above will increase. Eventually, the flow of water will enlarge the joint to the point that it can be considered a cave passage. Surface streams channeled into these caves are called sinking streams. The point at which these streams eventually resurface is called a karst spring or a resurging stream.

Bowling Green, Kentucky, is located on a plain dotted with so many dimples that it resembles the surface of a golf ball. In fact, it is referred to as the "sinkhole plain." A similar sinkhole marked plain extends from near Santa Rosa, New Mexico into Culberson County, Texas. Both of these plains are formed by a similar mechanism, the dissolution of soluble rocks. In Kentucky, the rock type is limestone. In New Mexico, the soluble rock is gypsum. As the rock dissolves and forms a cave passage, it weakens the support for overlying rock and soil. If enough rock is dissolved, the passage can begin to collapse. This collapse can continue upward until it reaches the surface. The result can be a collapsed cave entrance or just a closed depression in the surface.



Materials

- white chalk (broken into 1cm pieces)
- 100 ml beakers or 8 oz. plastic cups
- water
- white vinegar
- safety goggles
- piece of limestone

Procedure
Warm up: Ask students what a large field or meadow would look like if the bedrock underneath it began to dissolve. Discuss the ideas presented.

Explain to students that the very thing they just discussed happens in many parts of the world. Describe and discuss the weathering of carbonate rocks by acidic groundwater.

Describe landforms that result from the dissolution of soluble rocks.

Activity

1. Provide students with safety goggles.
2. Place 100 ml water in one of the beakers or plastic cups.
3. Place 100 ml vinegar in another beaker or cup.
4. Give each group of students two pieces of chalk. Have them place one in the water and the other in the vinegar and record their observations.

Wrap Up: Explain to the students that chalk is a type of limestone made of the shells of tiny animals.

Show the class a piece of limestone. Have them list similarities and differences between chalk and limestone. Be sure to point out that they are chemically similar. Ask the students what they would expect to happen if the limestone was exposed to a weak acid like vinegar.

Review the manner in which caves form as soluble rocks are dissolved by mildly acidic groundwater.

Assessment

Have students

- describe what happens to limestone when it is exposed to acidic groundwater.
- describe surface features found in areas underlain by soluble bedrock.

Extensions

Have students research pollution problems found in karst aquifers. Examples of aquifers include those found in the karst areas of the eastern US (Kentucky, Tennessee, northwest Georgia, northeast Alabama, Missouri and Florida would be good places to start). Also, the Edwards Aquifer of central Texas would be a good topic of study. Have them describe the most common sources of pollution, research methods, and activities being done to slow or prevent pollution.

Have the students study the effects of temperature, chalk size, and concentration of acid on the rate at which the chalk dissolves.

Conduct the same experiment using chips of limestone.

Resources

Feather, Ralph, et al. 1999. *Glencoe Earth Science.* Westerville, OH: Glencoe/McGraw-Hill.

Moore, G.W., and Sullivan, G.N. 1978. *Speleology: The Study of Caves.* Teaneck, NJ: Zephyrus Press, Inc.

VanCleave, Janice. 1991. *Janice VanCleave's Earth Science For Every Kid.* New York, NY, John Wiley & Sons, Inc.